CHAPTER 3
WATERSHED STUDIES

3.1 Introduction

Watershed studies shall be conducted to:

- determine the effects of a proposed development on the public drainage system
- establish the post-development 100-year floodplain
- identify existing drainage problems
- identify potential locations for regional stormwater facilities that address both flood control and water quality
- establish design criteria over and above the design criteria specified elsewhere in this manual to correct or improve existing drainage problems
- develop a stormwater management plan for the watershed to minimize future drainage problems and reduce existing problems

3.2 Data Collection

3.2.1 Data Sources

Appendix A lists numerous sources for obtaining mapping and other reference materials required as part of a watershed study.

3.2.2 Required Data

The following data shall be collected:

Watershed Characteristics
Determine the size of the contributing drainage area, expressed in acres, from the following:

- 2' contour maps with field checks to determine any significant changes in the contributing drainage area such as:
    - lakes
    - sinkholes
    - flood control structures
    - grade changes which have occurred since preparation of the map

Watershed Land Use
Document the existing and future land use. Information on existing land use can be obtained from:

- aerial photographs (conventional and infrared)
- LFUCG zoning maps and the most current LFUCG Comprehensive Plan
- USGS and other maps
- landsat (satellite) images
- soil maps

Existing land use data for small watersheds can best be determined or verified from a field survey. Use field surveys to update information on maps and aerial photographs, especially in basins that have experienced changes in development since the maps or photos were prepared.

The Comprehensive Plan Land Use Map, Zoning Map, and the current Comprehensive Master Plan can be obtained from the LFUCG Division of Planning.

Streams, Rivers, Ponds, Lakes, and Wetlands
At all streams, rivers, ponds, lakes, and wetlands that will affect or may be affected by future development, collect the following data:

- boundary (perimeter) and elevation of the water surface
- water elevation for design storms specified in this manual

- detailed description of any natural or manmade spillway or outlet works including dimensions, elevations, material, and operational characteristics
- detailed description of any emergency spillway works including dimensions, materials, and elevations
- profile along top of any dam and a typical cross section of the dam
- use of the water resource (stock water, aquatic habitat, recreation, power, irrigation, municipal or industrial water supply, etc.)
- riparian rights and/or ownership(s)
- applicable water quality standards
- existing data describing the physical, chemical, and biological water quality
- identification of wetlands and sinkholes within the project boundaries or downstream of project in a location which may be impacted by storm water runoff

Roughness Coefficients

Estimate roughness coefficients, in the form of Manning's n values, for the entire flood limits of the stream within the reach to be evaluated. A tabulation of Manning's n values with descriptions of their applications can be found in Chapter 8.

Stream Profile

Obtain streambed profile data to determine the average slope. Where there is a stream gage relatively close, obtain the discharge, with date and time of the reading corresponding to the stream level.

Stream Cross-Sections

Obtain stream cross-section data where stage-discharge-volume relationships will be necessary.

Existing Structures

- Investigate any structures that may cause backwater or retard stream flow.
- Evaluate the manner in which existing structures have been functioning with regard to such things as scour, overtopping, damage, and debris.
- For bridges, determine span lengths, height, type of piers, and substructure orientation.
- For culverts, determine the size, inlet and outlet geometry, slope, end treatment, culvert material, and flow line profile.
- Take photographs of high water debris lines.
- Determine outlet structure (principal and emergency spillway) dimensions, material, inlet condition, headwater and backwater conditions, slope, and invert elevations.
- Determine an elevation profile along the top of the embankment for simple outlet structures.
- For water quality calculations, determine the storage volume below permanent pools.
- Identify local sources of contamination, such as livestock, siltation, junk piles, and other point sources.
- Make a record of the condition of the structure concerning erosion, degradation, and damage.
- Take photographs of all structures to document their overall and detailed condition.

- Inventory the sinkholes and their condition, and identify any sources of obstruction or local contamination. Take photographs to document the conditions of the sinkholes.

Acceptable Flood Levels
Determine the lowest opening elevation of structures where flooding is known to occur.

Flood History
Evaluate the history of past floods and their effect on existing structures. Information may be obtained from newspaper accounts, local residents, flood marks, or other evidence of the height of historical floods.

Obtain recorded flood data from the following agencies:

- U.S. Army Corps of Engineers
- U.S.G.S.
- Kentucky Division of Water
- LFUCG

3.2.3 Documentation

Document the field review with dated field notes and photographs initialed by the reviewer. Include the documentation with the project plans and calculations submitted to LFUCG. Collect field data in accordance with GIS requirements of the LFUCG.

An example field inventory form is contained in Appendix B.

3.3 Runoff Models

3.3.1 General

The Stormwater Management Model (SWMM) or models using NRCS methods like HEC-HMS shall be used for hydrologic modeling. More information is contained in Chapter 5.

3.3.2 Subbasin Data

Subbasin data shall be collected in accordance with the following requirements:

- Delineate watershed subbasins so that average subbasin size is 10-50 acres and maximum subbasin size does not exceed 200 acres.
- Determine existing percent imperviousness from Table 3-1.
- Calculate overland slope from an average of at least three slope measurements of the subbasin terrain.

TABLE 3- 1
LAND USE IMPERVIOUSNESS

Land Use	Percent Impervious
Residential	
1/8 acre lots	65
1/4 acre lots	38
1/3 acre lots	30
1/2 acre lots	25
1 acre lots	20
Commercial	85
Industrial	72

3.3.3 Open Channel and Pipe Data

Collect the following data:

- Length
- Size of the channel or pipe
- Manning's n (Chapter 8)
- Upstream and downstream invert elevations
- Slope

3.3.4 Structure Data

When assembling a watershed model, stage-area-storage-discharge relationships shall be determined for all structures in the model.

- Calculate the stage-discharge curve for each structure.
- Using the 2-foot contour lines and field information, calculate a stage-area-storage relationship for each structure in the model. Include storage below the permanent pools. The stage-area information will allow the model to account for evaporation during continuous simulation.
- Combine the stage-discharge curve with the stage-area-storage curve to make one table for input into the model.

3.3.5 Error Analysis

When all the data is entered, run the model and check for errors in the run. Look for mass balance problems, model connectivity, correct data input, and proper model execution.

3.3.6 Calibration

The model should be calibrated against historic stream flow data if available.

3.4 Post-Development Floodplain Analysis

3.4.1 General

Once the runoff model is complete, post-development floodplains shall be determined with the United States Army Corps of Engineers' HEC-RAS computer program. This program will also provide results to indicate roadway and structure flooding. The design storm for floodplain analysis is contained in Chapter 5. This portion of the chapter details how to build the HEC-RAS input file for a watershed study.

3.4.2 Post-Development Floodplain Definition

The post-development floodplain shall be determined for streams shown as waters on Fayette County GIS waters coverage. The post-development watershed condition shall be based on future land use.

3.4.3 Cross-Sections

HEC-RAS determines floodplains based on cross-section data provided by the user. The following methodology shall be employed when developing cross-sections.

- Starting at the most downstream end of the study area, locate a cross-section at least every 200 feet until the upstream end of the study area is reached.
- Orient the cross section so that it is perpendicular to the contour lines.
- Using a 2' contour map, determine stations and elevations along each cross-section.
- Determine the station along the left side and the station along the right side of each cross-section that corresponds to the top of bank.
- Determine the downstream reach length from each cross-section to the preceding cross-section along the left bank, centerline, and right bank.

The data outlined above are required for each cross-section. If a cross-section happens to fall where a tributary intersects the channel, then employ one of the following two options.

- Delete the tributary-impacted cross-section from the analysis.
- Copy the stations and elevations from the downstream cross-section to the tributary-impacted cross-section, but increase all the elevations along the tributary-impacted cross-section by the difference in elevation of the centerline of the two cross-sections.

If tributaries are to be modeled, treat them similarly to the main stream by working from downstream to upstream and spacing cross-sections at 200' intervals.

3.4.4 Roughness Values and Coefficients

Working from downstream to upstream, specify the following roughness values and coefficients:

- left bank = Manning's n from Chapter 8

- right bank = Manning's n from Chapter 8
- stream channel = Manning's n from Chapter 8
- contraction coefficient = 0.10
- expansion coefficient = 0.30

If the entire stream reach has the same set of roughness values from downstream to upstream, then only specify these values at the beginning of the input file.

3.4.5 Flow and Water Surface Elevations

The results from SWMM or HEC-HMS will provide the flows and water surface elevations at flow control structures for each HEC-HMS run.

3.4.6 Rounding of Water Surface Elevations

The water surface elevations from HEC-RAS shall be rounded to the nearest 0.1'.

APPENDIX 3-A – SOURCES OF DATA

- Flood Plain Delineations and Studies

  Federal Emergency Management Agency
  Flood Map Distribution Center
  6930 (A-F) San Tomas Road
  Baltimore, Maryland 21227-6227
  www.fema.gov/msc/femahome.htm

  Lexington-Fayette Urban County Government
  Division of Engineering
  200 E. Main Street
  Lexington, Kentucky 40507
  (859) 258-3410

  Kentucky Department for Environmental Protection
  Division of Water
  14 Reilly Road
  Frankfort, Kentucky 40601
  (502) 564-3410

- Hydraulic Studies

  Kentucky Transportation Cabinet
  Department of Highways
  State Office Building
  Frankfort, Kentucky 40601
  (502) 564-4890

  Lexington-Fayette Urban County Government
  Division of Engineering
  200 E. Main Street
  Lexington, Kentucky 40507
  (859) 258-3410

  U.S. Army Corps of Engineers
  Louisville District
  P.O. Box 59
  Louisville, Kentucky 40201
  (502) 582-5601

  Kentucky Department for Environmental Protection
  Division of Water
  14 Reilly Road
  Frankfort, Kentucky 40601
  (502) 564-3410

- Meteorological Data

  Midwestern Climate Center
  2204 Griffith Drive
  Champaign, Illinois 61820-7493
  (217) 244-8226
  mcc.sws.uiuc.edu

National Oceanography and Atmospheric Agency (NOAA)
Climate Data Center
Ashville, North Carolina 28801
www.crh.noaa.gov/lmk/climate.htm

U.S. Geological Survey, Water Resources Division
9818 Bluegrass Parkway
Louisville, Kentucky 40299-1906
(502) 493-1900
www.usgs.gov/public/data.html

- Water Quality Data

  Kentucky Department for Environmental Protection
  Division of Water
  14 Reilly Road
  Frankfort, Kentucky 40601
  (502) 564-3410

  U.S. Geological Survey, Water Resources Division
  9818 Bluegrass Parkway
  Louisville, Kentucky 40299-1906
  (502) 493-1900
  www.usgs.gov/public/data.html

  Lexington-Fayette Urban County Government
  Division of Engineering
  200 E. Main Street
  Lexington, Kentucky 40507
  (859) 258-3410

APPENDIX 3- B – EXAMPLE FIELD INVENTORY FORM

Pond/Culvert Inventory Data Sheet

Pond/Culvert ID: _____ Wet or Dry Location: _____

Purpose of Structure: ☐ Sediment/Retention ☐ Farm pond ☐ Road crossing

Usage of Structure: _____ Crew: _____
Date: _____
Project: _____

Roll #	Picture #	Photograph Description
_____	_____	Upstream looking at dam
_____	_____	Inlet
_____	_____	Outlet
_____	_____	Emergency spillway (if applicable)

Physical Data

Dominant ground surface in water storage area: ☐ Bare soil ☐ Riprap ☐ Light vegetation ☐ Concrete ☐ Dense vegetation

Length to Width Ratio: ☐ 0.5-1 ☐ 1-1 ☐ 2-1 ☐ > 2-1

SKETCH approximate geometry on back.

Structure Data

Impoundment: ☐ Earthen ☐ Concrete ☐ Natural Basin ☐ Other _____

Outlet Condition: ☐ Little or no erosion ☐ Fairly eroded ☐ Severely eroded ☐ Damaged ☐ Debris Present

Inlet Condition: ☐ Little or no erosion ☐ Fairly eroded ☐ Severely eroded ☐ Damaged ☐ Debris Present

Signs of Water Flowing Over Dam: ☐ Yes ☐ No Describe: _____

Primary Inlet Type	**Size (in.)**	**# Outlets**	**Material**
Circular Pipe	_____	_____	☐ Concrete
Box Culvert	_____	_____	☐ Metal
Instream Weir	_____	_____	☐ PVC
Hor. Elliptical Pipe	_____	_____	☐ Other _____
Vert. Elliptical Pipe	_____	_____	**Manning's n**
Other _____	_____	_____	_____

Primary Outlet Type	**Size (in.)**	**# Outlets**	**Material**
Circular Pipe	_____	_____	☐ Concrete
Box Culvert	_____	_____	☐ Metal
Instream Weir	_____	_____	☐ PVC
Hor. Elliptical Pipe	_____	_____	☐ Other _____
Vert. Elliptical Pipe	_____	_____	**Manning's n**
Other _____	_____	_____	_____

Emergency Spillway Dimensions (if applicable)

Depth: _____ in. Material: ☐ Riprap ☐ Concrete
Width: _____ in. ☐ Vegetation ☐ Other _____

Additional Comments: (ex: livestock access to stream/pond; silt present in culvert, etc.)

_____

_____

Survey required? ☐ Yes ☐ No